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Specifying A Moisture Analyser

Issues for Consideration

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Section 1

Introduction

Objectives

This document is designed to help the users of moisture analysers to identify and select those performance criteria which are most important to them when choosing an appropriate analyser for an application.

In principal, any measurement is about collecting reliable data, quickly!

In the field of moisture measurement, there are many factors that will influence the final choice of instrument. An analysis of the commercial and technical issues that any such instrument must address will help to give an insight into what are the most important features for a successful implementation.

The advice in this guide should be treated as a starting point. Specific issues can be addressed by dealing with competent suppliers who, from practical experience, understand the operator's problems and can give sound advice to help achieve a successful implementation.

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Section 2 — Why Measure Moisture?

Reasons Moisture is Important

In any moisture measuring application, the driving force behind the need to monitor is usually associated with one of the following:-

1. The protection of people, process or plant will reduce risk and unscheduled cost (i.e.: the '*cost of failure*').

2. An increase in productivity to enable better use of time and resources.

3. The improvement of Quality Control provides greater confidence and the ability to reduce tolerances, which in turn results in reduced wastage costs.

Once we have established a list of objectives, we can begin to investigate the factors that can affect the achievement of those objectives. Generally, we can categorise the problems facing the user in to four distinct groups:

4. How will the sample be protected from 'change' during its transportation from the process to the hygrometer (i.e.: how do we ensure the sample is representative of the process)?

5. What are the analyser's performance characteristics that will impact on the integrity of the measurement?

6. What are the acceptable performance tolerances for the instrument and for what period of time must these tolerances be maintained without intervention?

7. What is a practical methodology for validating performance?

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Section 3 — Problems & Myths

The Difficulty of Measuring Water

The measurement of water is commonly grouped with the analysis of much more readily detectable molecules. Very often, people overlook the fact that water is naturally abundant in the natural world, is physically very small and has a polar nature.

> ***This means that water is everywhere (in the air, in our bodies, in most 'solid' materials), can permeate into the smallest of holes due to its size and it sticks to everything because it has a positive charge!***

When we also consider that water changes states within a very narrow temperature band, and has broad solvent properties, it becomes evident that measuring water molecules with precision in an industrial application is very difficult! The soluble and insoluble contaminants that are ever present in nearly all processes are only too willing to interact with the measurement!

It is the interaction of the above factors within the process that will influence the structure of an instrument specification. However, before we can address the objectives we identified in *Section 2*, we first have to dispel some common myths . . . . .

Myth 1 — "Isn't an on-line measurement more complex and expensive than a trend analysis?"

Often, users wish to monitor a *trend* and falsely believe that both initial design and on-going support costs will be less than for an on-line analyser, because they believe that accuracy and / or calibration are less important to a trend analysis than a quantitative analysis.

However, if a trend value is being used to trigger an alarm, then some quantitative value must be ascribed to the alarm condition, which ultimately implies a need for precision.

Ultimately, this means that to maintain these levels of precision, regular calibration of the instrument is mandatory irrespective of whether the user is trying to determine a *trend* or *qualitative* measurement value.

Myth 2 — "Absolute methods require no calibration, do they?"

All hygrometers need calibration – without exception! All of the technologies which are listed below claim to be absolute operating principles, but they still require calibration and adjustment to deal with attenuation resulting from contamination effects:-

- *Electrolytic*
- *Mirror*
- *Laser*
- *Infra-Red*
- *Oscillating Crystal*

Why do they require calibration? Because no hygrometer directly 'counts' every water molecule!
The presence of water (as a polar molecule) means that it will interact with its surroundings on a molecular level as well. It is these interactions that result in signal attenuation.

Ever present trace contaminants will build up cumulatively in any process, interacting with both water content and sample systems and ultimately leading to a loss of the instrument's sensitivity.

All instruments therefore need recalibration in order to correct for drift.

Myth 3

"A fast responding moisture analyser is only needed for spot-checking. Speed is less important for on-line applications, isn't it?"

Not true! Consider the scenario where an injection of water into an application will cause damage to the process, such as a catalyst reaction where the moisture balance is critical due to the rapid changes in temperature and pressure that will occur during the reaction stage.

If a slow responding analyser takes 10 minutes to settle to equilibrium, but moisture is introduced for a brief 10 second period, then it is very likely that the analyser will only see an incremental build up of moisture, and an even slower decay. Often the amplitude will be insufficient to trigger the alarm level at all, which leads to critical failure of the catalyst. Signal interpretation is therefore directly related to the speed of response of the analyser.

There is no advantage in having a slow responding analyser, but significant benefits in having a fast device. The improved precision and early-warning capability of the fast analyser help to protect the process, plant and the instrument itself.

Myth 4 — "Accuracy can be stated as a simple ± value or as a % of scale, can't it?"

In practice, no! This is because in most processes the operator will not wait indefinitely for stability to be achieved. To define accuracy, we need to know the period of time over which we are trying to measure accuracy.

Take the example of a watch that has stopped:-

> *If we take the battery from the watch, the hands will stop moving but, at the time of removing the battery, the display is accurate. For every second of time which elapses, the perceived accuracy of the watch changes despite the fact that it appears to be very stable!*
>
> *After 12 hours, the watch will again be accurate, but simply because the process conditions coincide with its indicated display, and not vice versa!*

This demonstrates that accuracy is dependent upon stability, repeatability and the speed of response of the instrument in question. Hence, if we intend to calibrate a hygrometer it is vital to know not just its response speed, but also the stability and repeatability of any generating source used to calibrate it.

Myth 5 — "Aren't validation and calibration the same?"

Calibration is the process of comparing an instrument which is being used measurement against an authoritative reference, to identify any bias or error in the readings. Calibration does not mean '***the adjustment of the instrument to read correctly***!'

Validation is the comparison of an instrument reading against that of a calibrated instrument in a known condition. Generally, validations can be performed on-site and precise calibrations are performed in a laboratory, where parameters such as temperature can be more readily controlled.

Without a clear understanding of such terms operators will make decisions based upon false assumptions, which will result in increased resource demands post-installation. Sometimes these extra resources cannot be funded or supported in the field, resulting in unreliable data.

The specifier needs to consider carefully the following issues:-

- *How to design an appropriate test methodology for the hygrometer?*
- *What is the cost of purchasing / supporting such a methodology?*
- *What practical issues affect on-site validations / calibrations?*

Such issues can be significant overheads that directly impact on the successful long-term collection of reliable data, for the life of the system. As such, they ought to be prime considerations in any decision making process.

Now that we have examined, and refuted, some of the common myths that exist regarding hygrometry, we can begin to address the requirements of our analyser specification that we identified in *Section 2*.

Section 4

The Specification

The Sample

"How will we protect the sample from being changed during transportation to the hygrometer?"

All materials hold different quantities of water according to their temperature. As such, any absorbed water in a sample pipe will maintain a fixed amount of water in equilibrium with its temperature. Whenever the temperature is disturbed, so is the water holding capacity of the material that is conveying the sample.

Raise the temperature and water is released from the pipe into the sample, whilst cooling the pipe absorbs water from the sample into the pipe.

The specifier needs to be aware of this process and construct a suitable mechanism to deal with it. Heat tracing is one obvious way. Often people ask:-

"If my sample lines are heated, why do I need temperature control of my Sensor?"

Issues of temperature apply equally to Sensors as they do to sample systems! *The sensitivity of any Sensor will vary according to its surface temperature.*

If the operating temperature of the Sensor is unspecified, or different from the temperature at which it was calibrated, then the operator cannot know with surety the analyser's sensitivity (i.e.: its ability to 'see' water), which will destroy the validity of the calibration.

If a Sensor is temperature controlled we are able both to calibrate and *operate* at the same temperature, thus transferring laboratory accuracy out into the field and maintaining the traceability of the calibration.

Temperature stability is therefore a vital and mandatory parameter of any humidity measurement because temperature directly affects the sensitivity of both the sample system and the Sensor.

Ideally, the temperature of the Sensor should be maintained above any ambient variations that are likely to be encountered during monitoring.

Apart from temperature, the following will all affect the integrity of the sample:-

- *Gas Composition*
- *Pressure Drops*
- *Materials of Construction of the Sample System*
- *Filtration*
- *Sample System Layout*

Generally, keeping the sample system design as simple as possible will yield the best results.

Instrument Performance

"How do we establish the performance characteristics that impact on the integrity of the measurement?"

There are probably over 30 characteristics that can be considered relevant when specifying a hygrometer. Of these, the most obvious include:-

- *Stability*
- *Speed of Response*
- *Repeatability*
- *Thermal Stability (of Sensor)*
- *Flow Independence*
- *Resistance to (and recovery from) Contamination*

- *Hysteresis Characteristics*
- *Linearity*
- *Interference Errors*
- *Robustness*
- *Validation / Calibration and Traceability to Standards*

Each of these topics must be considered carefully in order for the final system to be a success. The user has to consider how variances in each of these parameters will affect the final outcome.

Performance Tolerances

"What constitutes acceptable performance for the hygrometer?"

In an *ideal world* the operator would have unlimited time to establish the absolute accuracy of a reading. He would work in pure and uncontaminated conditions that would ensure that the reading is representative. Finally, he would never need to calibrate or service his instruments!

In the real world of industry, exactly the opposite is true!

It is therefore important to define what constitutes acceptable performance, and how it can be monitored between routine service and calibration work.

A basic truth of science is that contamination, however small, is a fact of life. Hence, it is logical that everything becomes contaminated over time. The logic follows that any signal being measured over a period of time is also being attenuated with time under the same conditions. Subsequently, it is clear that every hygrometer will need to be calibrated eventually. The operator has to define the tolerance of performance that is acceptable, as this will directly impact on the required frequency of calibration.

Due to the fact that these tolerances are inter-dependent, and affected by external factors such as contamination, it is very difficult for the specifier to be assured that a system will meet such specifications without some form of evaluation process against known test conditions. ISO guidelines can help, but more importantly the user must be willing to reach a practical compromise which balances the performance of the system against the cost of maintenance. On that basis an appropriate validation method can be developed that tracks performance against time.

Validation Principles

"How do we develop a practical validation methodology?"

Several approaches exist by which a user can validate the performance of his instrument. Starting with the most precise first, they are:-

1. *Operate a moisture standard which is situated directly at the point of test, to operate as a prime comparison*. This mechanism has the least error associated with it but is most costly due to the high degree of quality control necessary to maintain the traceability of such a standard.

2. *Use a transfer standard mechanism to validate the analyser.* This method is less precise than Option 1 because second order errors will be introduced in calibrating the transfer standard analyser.

3. *Send the analyser for calibration against a known standard.* This method offers the risk of greater errors due to the potential for handling and reinstallation errors which may disturb the calibration or local differences in temperature, pressure etc.

4. *For comparison purposes, use generators that have third order traceability.* Methods such as 'calibration gases' in cylinders are the least precise and potentially most misleading method of all. They can introduce very large errors due to poor handling and methodology or from a lack of understanding the impact that the operating conditions will have on such a 'generator' and associated sample systems.

Once a validation process has been selected, a suitable method must then be implemented to dynamically test the performance characteristics of most interest to the user.

This programme usually involves at least two separate moisture levels that can be generated and introduced to the analyser as a step-change, in order to eliminate any settling time issues with the generator that may mask the true performance of the hygrometer. Such a methodology should be able to help establish the speed of response, stability and / or repeatability of the analyser under review.